GROWTH CHARACTERISTICS, YIELD COMPONENTS, WATER AND NUTRIENT USE OF FOUR SPRING WHEAT CULTIVARS

C.A. Campbell, H.W. Cutforth, J.M. Clarke, Y.W. Jame and R.M. DePauw
Agriculture Canada Research Station
Swift Current, Saskatchewan

Introduction

We have recently licensed a new type of spring wheat, which is commonly described as a triple-M (medium protein, medium gluten strength, medium kernel hardness) wheat (now called Canada Prairie Spring). This wheat, which is typified by HY320, was developed at the Agriculture Canada Research Station in Swift Current. It is a high yielding semidwarf variety. In 120 tests over 9 years on the Prairies, HY320 has outyielded Neepawa by an average 29%. We have also been working on a promising high yielding durum line (DT367) which, on average, outyields Wakooma by about 10-15%.

It was felt that it would be informative to determine (a) how the differences in yield potential between these four wheat cultivars were brought about; and (b) to determine whether the higher yielding cultivars would use and require more soil moisture or nutrients than the standard varieties commonly grown.

Materials and Methods

Experiment 1 -- Development, Yield Components, Water and Nutrient Use by Four Wheat Cultivars - Good Summerfallow (1984)

Neepawa (HRS wheat), HY320 (triple-M wheat), Wakooma and DT367 (durum wheats) were grown on summerfallowed land in a completely randomized, replicated (6 reps.) test on a Wood Mountain loam soil at Swift Current. The test was laid out on two discrete blocks, each made up of 24 plots (4 cultivars x 6 reps). One block of plots, used for yield only, consisted of the 24, 4-row plots, each 3 m x 0.91 m. The second, large block, which was located adjacent to the first block, had 24, 3.0-m x 3.65-m plots; these were used for destructive plant and soil sampling at various growth stages. The entire area was fertilized with 65 kg/ha P_2O_5 and 15 kg/ha N as 11-48-0 and 31 kg/ha N as urea, all broadcast and incorporated prior to seeding. The test area was sprayed on June 12 with Hoegrass for control of green foxtail and on June 19 with Buctril-M for control of broadleaf weeds.

Both the destructive plots and the yield plots were seeded on May 9 with a small plot seeder, which seeds 4 rows each pass at a spacing of 22.85 cm at a rate of 800 seeds per plot (3 m x 0.91 m) (290 plants/m^2). In actuality the seeding rate would be slightly lower since the seeding starts just before entering the actual plot area.

The plan in 1984 was to grow the crop under good summerfallow moisture conditions. Thus irrigation would be limited and would be used when required to relieve periods of excessive drought. A total of 145 mm of irrigation was applied in 5 irrigations (25.4 mm on May 12, and the rest between July 9-23). Rainfall received between seeding and harvest (August 22) was 115.6 mm.

Plant Measurements

Plant samples were taken at 5 growth stages (viz., 4-leaf, ligule of last leaf visible, anthesis, soft dough, and at harvest) by sampling all plants in a 30-cm length of row from each plot.

At each stage the following measurements were made: number of plants; number of tillers; number of leaves on main culm and on other culms (separately); dry weight of leaves on main culm and others (separately); dry weight of main culm and other culms (separately); from anthesis -- the number of heads; at harvest -- number of spikelets per head for main tiller and other tillers;

number of grains per head for main tiller and others; number of heads; total grain weight; weight of straw; %N and %P in grain and straw. The N and P content of stems, leaves and heads were determined at each growth stage.

At anthesis the heads of 100 similar main culms in each plot were tagged and from 5 days after anthesis, 5 heads per cultivar per replicate were removed, taken to the laboratory and the grains in the centre row of florets removed, dried overnight and weighed. This analysis was repeated every two days until maturity. All plant samples were dried at 70°C overnight prior to weighing.

Soil Measurements

Just prior to seeding and immediately after harvest, a Giddings truck was used to take soil samples to a depth of 120 cm (0-15, 15-30, 30-60, 60-90 and 90-120 cm). At each growth stage soil samples were taken by hand coring to 90-cm depths (same increments). Two cores were taken per plot and like depths were bulked. Soil moisture (gravimetrically), NO_3- and exchangeable NH_4-N and $NaHCO_3$-P were determined at each sampling.

Experiment 2 -- Development, Yield Components, Water and Nutrient Use by Four Wheat Cultivars - Optimum Moisture and Nutrition Conditions (1985)

In 1985 the experiment was repeated under optimum moisture and nutrient conditions. The following changes were made:

(1) The size of the destructively-sampled plots was increased to 3.0 m x 4.6 m, and the length of row samples each time increased to 50 cm.

(2) Irrigation water was estimated weekly, using Ritchie's "Ceres" model and water added to bring the soil to about field capacity whenever the rooting zone was expected to reach 50% of the

available water capacity. A total of 460 mm of irrigation water was added during 14 irrigation events.

(3) On April 29, 116 kg/ha N and 58 kg/ha P_2O_5 were applied as 26-13-0 to a stubble field and this was worked into the soil during seedbed preparation. Again on June 10th, a further 58 kg/ha N and 29 kg/ha P_2O_5 were applied on the crop, for a total 174 kg/ha N and 87 kg/ha P_2O_5.

Rainfall between seeding on May 7 and harvest of the last cultivar on September 20, was 140 mm.

The plots were sprayed for grassy weeds with Hoegrass II on June 3 and for grasshoppers on July 27. There was some root-rot infestation of a few plots of Wakooma and smut in several of the HY320 plots.

Results and Discussion

1. Rate of Development

The effect of optimizing moisture supply and the much higher rates of nutrients required to complement this extra water may result in a considerable lengthening of the time to reach maturity (Table 1). Under dryland conditions Neepawa seeded on stubble land took 91 days and HY320 97 days to reach maturity (a separate experiment not reported here). Under irrigation, Neepawa took 119 days and HY320 127 days to reach maturity. Optimizing growing conditions resulted in approximately a 30-day extension of the time to reach maturity. This underscores one possible problem for irrigated crops in Saskatchewan -- the extended growth period could expose the crop to a greater chance of succumbing to early frost. Neepawa was the earliest to mature and HY320 the latest.

Table 1. Days from seeding to maturity in 1985

	Neepawa	HY320	Wakooma	DT367
Dryland*	91	97	95	93
Irrigated**	119	127	121	127

* Observations from a separate study; rainfall = 100.8 mm.
** Rainfall + irrigation = 600 mm; both plots seeded May 7.

2. Vegetative Characteristics

Some of the vegetative characteristics at their peak (ligule last leaf visible) are shown for each year in Table 2. Tillers per plant was erroneously not taken in 1984 but in 1985, under full irrigation, Neepawa and HY320 produced 1-2 tillers/plant more than the durums. In both years HY320 and the two durums grew at least one more leaf on the main tiller than Neepawa (i.e., developed at least one more node). The number of leaves developed appeared to increase with water (fertility). Leaf area index (LAI) was not affected by cultivar but, as expected, it increased with improved growing conditions averaging 4.5 cm^2/cm^2 soil for well irrigated and 3.6 cm^2/cm^2 soil for moderately irrigated conditions (1984); (it averaged 1.9 cm^2/cm^2 soil for a dryland experiment in 1985).

Table 2. Vegetative Characteristics at Ligule of Last Leaf Visible Stage

Treatment	Variety	Tillers/ plant	Main culm leaves/plant	LAI (cm^2/cm^2)
1984 irrigated	Neepawa	ND	3.6	3.4
(261 mm)	HY320	ND	4.5	3.8
	Wakooma	ND	5.1	3.6
	DT367	ND	4.2	3.6
Signif. (P)			<0.01	NS
1985 irrigated	Neepawa	5.1	4.1	4.5
(600 mm)	HY320	4.5	6.2	4.7
	Wakooma	3.5	6.4	4.6
	DT367	3.0	5.6	4.2
Signif. (P)		<0.05	<0.01	NS

We expressed the weight of each plant organ as a proportion of its total weight (Figs. 1 and 2) and compared the two durums as one pair, and HY320 and Neepawa as a second pair. In each case there was no effect of cultivars on the proportioning of DM into the leaves but in each case the higher yielding cultivar (i.e., HY320 and DT367) had a lower proportion of the total DM left in the stems (after anthesis) and a greater proportion being located in the heads. It was also observed that the proportion of the plants' DM appearing in the heads at harvest decreased for the more well-irrigated and fertilized system (1985) compared to 1984 (Figs. 1 and 2).

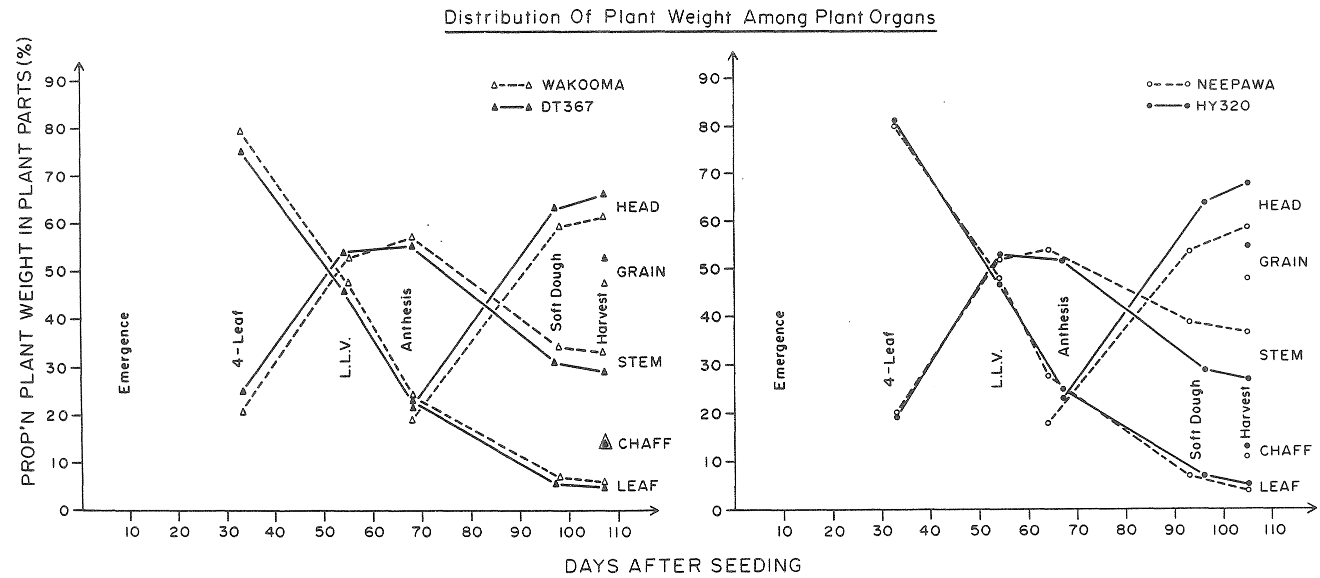

Fig. 1. Distribution of plant weight among plant organs as a function of development stage for 1984.

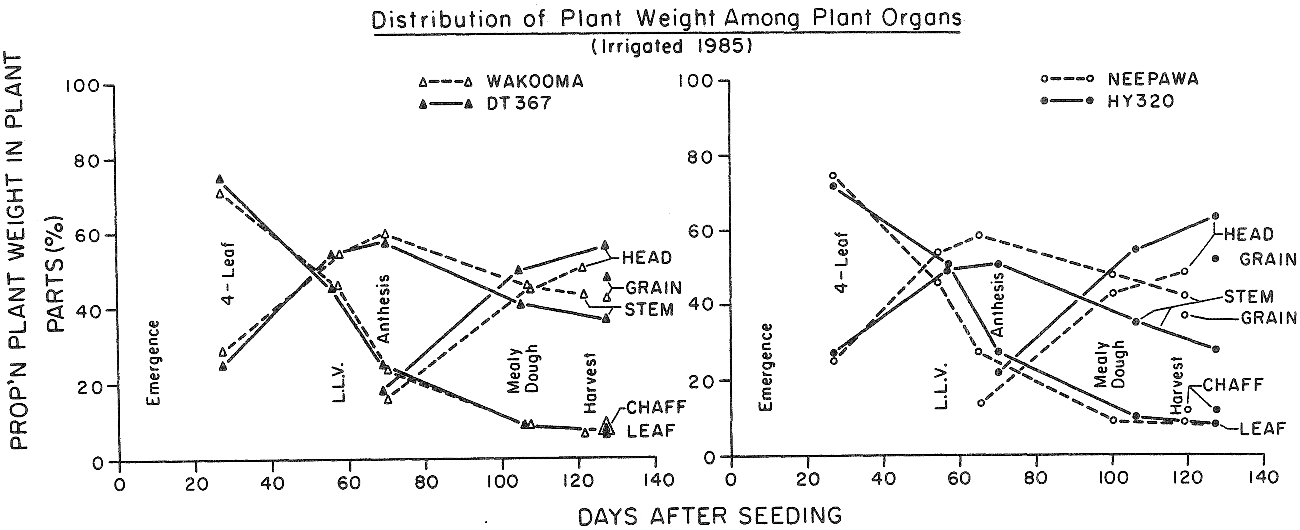

Fig. 2. Distribution of plant weight among plant organs as a function of development stage for 1985.

3. Yield and Components of Yield at Harvest

In 1984 yields were not significantly affected by cultivar although HY320 tended to outyield the others (Table 3). Under heavy irrigation in 1985, HY320 yielded the most (8200 kg/ha), followed by DT367 (7690 kg/ha), then Wakooma (7065 kg/ha) and Neepawa (5715 kg/ha) based on the yield plots (Table 3).

Table 3. Yield and Components of Yield

Year	Variety	Heads/ row	Spikelets/ head	Grains/ head	Grains/ spikelet*	Wt/grain (mg)	Yield (kg/ha)
1984 irrigated	Neepawa	42	11.1	24.8	3.2	30.4	3161
(261 mm)	HY320	30	12.3	33.6	3.9	39.4	3464
	Wakooma	28	14.0	30.2	3.1	38.7	3384
	DT367	25	14.8	34.7	3.2	40.8	3554
Signif. (P)		<0.01	<0.01	<0.01		<0.01	NS
1985 irrigated	Neepawa	103	12.2	24.4	3.0	32.7	5715
(600 mm)	HY320	74	15.2	41.6	3.8	39.2	8200
	Wakooma	71	13.6	30.4	3.2	39.2	7065
	DT367	72	15.1	33.3	3.2	43.1	7695
Signif. (P)		<0.01	<0.01	<0.01		<0.01	<0.01

* Central spikelets of main spike

In each year the number of heads per unit length of row was highest for Neepawa with the other cultivars being generally similar (Table 3). In both years Neepawa had the lowest number of spikelets developed per head; the durums had the most in 1984 and DT367 and HY320 the most in 1985 (Table 3). HY320 consistently filled more of its florets with grain (Table 3). Neepawa had by far the least number of grains/head in each year while DT367 had slightly more than Wakooma (due to greater number of spikelets/head). DT367 had the heaviest kernels (41-43 mg), Wakooma and HY320 were equal at 39 mg, and Neepawa much lighter at 30-32.5 mg (Table 3).

Thus, Neepawa's low yields are due to its smaller heads with fewer, lighter kernels while HY320's greater yields are due to its ability to fill more of its florets with grain, which are reasonably heavy; further, HY320 has a reasonable number of viable heads. The only advantage Neepawa has over the other cultivars is its ability to tiller. The high-yielding durum (DT367) had heavier kernels than HY320 but its inability to fill a greater proportion of its florets with grain was the main reason why it did not yield as well as HY320.

4. N and P Concentration in Plant in 1984 Experiment

The amount of N and P in the above-ground plant material per 30-cm row, at harvest, is presented in Table 4. The grain protein content is also shown. HY320 had the highest amount of N in the head but Neepawa had the highest grain protein concentration followed by Wakooma. Although HY320 had the highest amount of N in the heads it also left twice as much N in the vegetative material. In the vegetative parts, HY320 differed from the other three cultivars in that its stem maintained a higher N concentration from anthesis to maturity (Fig. 3). If this N could be mobilized into the grain without sacrificing yield it might have almost as high a protein as Neepawa. In any event, there was 33% more total N in HY320 than in the other three cultivars, which indicates that it may require a higher fertilizer N recommendation than Neepawa and the durums. However, there was no difference in the amount of P in HY320 and Neepawa or Wakooma and these had only slightly more than in DT367 (Table 4). Thus, it does not appear that the fertilizer P recommendation for HY320 will need to be adjusted.

Table 4. Amount and Concentration of N and P in the Plant at Harvest - 1984

Variety	*Total N and P in plants in 30-cm row				Grain		
	N		P				
	mg	% of Neepawa	mg	% of Neepawa	% P	% N	% Protein
Neepawa	957	100	155	100	0.47	2.70	15.5
HY320	1269	133	165	106	0.38	2.32	13.3
Wakooma	908	95	155	100	0.45	2.46	14.1
DT367	910	95	138	89	0.38	2.29	13.2

*Above-ground material

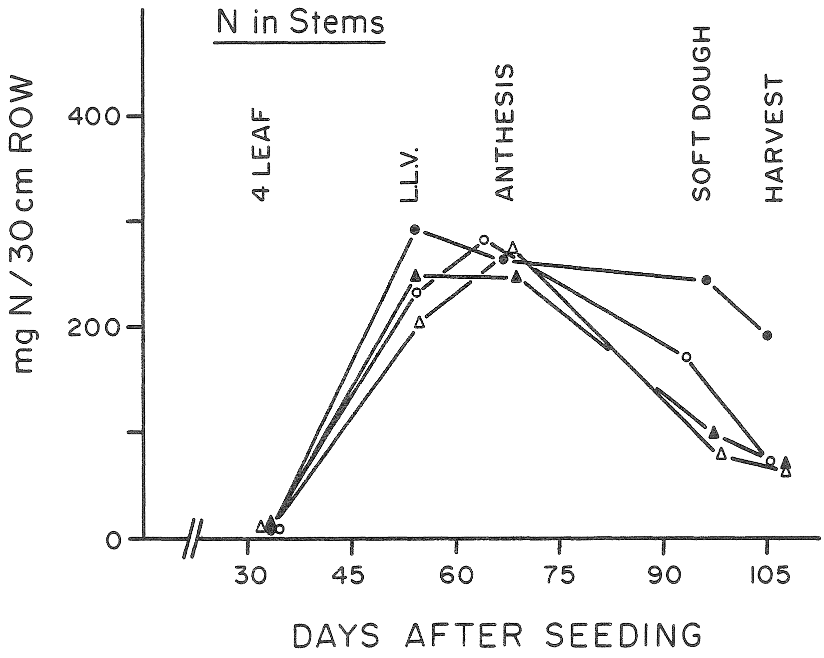

Fig. 3. N content of stems per 30-cm length of row at specified growth stage (1984).

(-●- HY320; -o- Neepawa; -△- Wakooma; -▲- DT367)

5. Water Used from 0-90 cm Depth (1984 & 1985)

The amount of water used by the four cultivars during the various growth periods was calculated as the sum of the change in water between periods plus the rainfall and irrigation occurring during the period (Table 5). The values in each period vary somewhat because cultivars were sampled on different dates depending on their rate of growth. However, in both years there was no difference between cultivars in the total water used between seeding and harvest. Thus, the moisture use efficiency for these cultivars was directly proportional to their grain yields.

Table 5. *Water Used from Top 90 cm of Profile by Crop

Variety	Seeding to anthesis	Anthesis to harvest	Seeding to harvest
1984 irrigated			
Neepawa	20.82	14.23	35.05
HY320	20.52	14.30	34.82
Wakooma	20.51	14.53	35.04
DT367	21.77	13.7	35.47
Average	20.91	14.19	35.10
1985 irrigated			
Neepawa	34.90	34.10	69.00
HY320	39.02	28.98	68.00
Wakooma	40.69	28.00	68.69
DT367	39.21	31.04	70.25
Average	38.46	30.53	68.99

* Change in soil water in 0-90 cm depth plus period rainfall and irrigation.

Summary

A two-year study, carried out under limited and full irrigation at Swift Current, was used in an attempt to explain (a) by what means do the high yielding cultivars HY320 (a triple-M wheat) and DT 367 (a durum) outyield Neepawa and Wakooma, and (b) to determine whether the higher yielding cultivars will require more soil moisture or nutrients than is customarily recommended for hard wheats.

The findings were as follows:

1. Full irrigation (600 mm of rain plus irrigation) lengthened the time to reach maturation by as much as 30 days; this could expose the crop to frost damage in some years.

2. Neepawa in particular, and HY320 to a lesser extent, tillered more than did the durums, while HY320 and the durums produced at least one more leaf on its main culm (one extra node) than did Neepawa. LAI was unaffected by cultivar.

3. HY320 translocated more DM from stems to heads than did Neepawa and similarly DT 367 more than Wakooma. The proportion of the plants' DM appearing in the heads at harvest decreased with amount of irrigation.

4. In both years HY320 was the highest yielding cultivar although only in 1985, when rainfall and irrigation totalled 600 mm, were yield differences significant. In 1985 yields for HY320, DT 367, Wakooma and Neepawa were 8200, 7690, 7065 and 5715 kg/ha, respectively.

5. At harvest, Neepawa had by far the most heads and there was little difference between the other cultivars. Neepawa had the lowest number of spikelets developed (smallest heads) while HY320 and the two durums had about the same number. But, HY320 consistently filled about four florets per spikelet with grain while the other cultivars filled only three on average. The number of grains per head was therefore generally greatest for HY320, followed by DT 367 and Wakooma; Neepawa had by far the least.

6. HY320 differed from the other cultivars in that it maintained a higher concentration and amount of N in its stem to harvest. Thus, although HY320 took up 33% more N in the plant and had 21% more N in all heads than Neepawa, its grain protein was 13.3% compared to Neepawa's 15.5%. This suggests that there is opportunity to breed for greater N transfer from stems to grain in HY320. There was no significant difference in N content between the two durums.

7. These results suggest that we might need to increase N fertilizer rates by about 30 to 50% for HY320 compared to Neepawa, but there needs to be no

change in P fertilizer recommendations.

8. There was no difference between cultivars in the amount of available water used between seeding and harvest, in either year. Thus, water use efficiency was directly proportional to yield.

N.B. The N and P results are based on one year's data.